THE POTENTIAL OF DIVERSE PASTURES TO REDUCE NITROGEN LEACHING ON NEW ZEALAND DAIRY FARMS

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Abstract
The effect of dairy cows grazing diverse pastures on whole farm productivity and urinary nitrogen (UN) excretion was evaluated using the DairyNZ Whole Farm Model. Two farms running typical systems; Scott Farm in the Waikato region (stocking rate = 3.2 cows/ha) and Lincoln University Dairy Farm in the Canterbury region (stocking rate = 3.9) with Holstein-Friesian x Jersey crossbred cows, were modelled over the 2011-2012 season. The effect of diverse pastures was assessed using three scenarios; the standard pasture (the traditional New Zealand perennial ryegrass-white clover pasture mix; control), and this pasture combined with diverse pasture sown on 20 or 50% ('20% diverse' or '50% diverse') of the farm area, with the remainder sown in standard pasture. The diverse pasture comprised a mixture of standard pasture, chicory, plantain, prairie grass and either lucerne in the Waikato or red clover in Canterbury. Supplements were fed during deficits. The model outputs were farm-grown dry matter (DM) production, imported feed, milksolids production and UN. In both regions, the '20% diverse' resulted in 1-2% lower DM production, but the higher feed energy content reduced intakes resulting in 4-19% less imported feed, compared with the control. In the Waikato, the 6% lower DM production for the '50% diverse' compared with the control was only partly compensated for by increased energy content and an increase of 67% imported feed was predicted. In Canterbury, there was indication of diverse pasture benefiting from irrigation with 2% greater DM production and 46% less imported feed predicted for the '50% diverse', compared with control. Milksolids production was similar across treatments, except for an increase of 3% predicted for the '50% diverse', relative to the control in Canterbury. In both regions, feeding diverse pasture resulted in 3-7% less UN excretion. This study suggests that incorporating diverse pastures in New Zealand dairy systems can reduce UN excretion by dairy cows and mitigate the risk of nitrate leaching. However, the economic feasibility of diverse pasture-based systems is likely to be impacted by the effect of growing conditions on the farm feed base. Diverse pasture persistence and re-grassing costs were not taken into account in this study and, therefore, these results will need further verification.

Key words: Diverse pastures, urinary nitrogen, dry matter production.

Introduction

New Zealand dairy farming has mainly been based on perennial ryegrass (*Lolium perenne* L.)-white clover (*Trifolium repens* L.) pastures with crops (e.g. maize and brassicas) introduced over the past 2-3 decades to fill gaps in pasture forage availability (Bryant et al., 2010). The high protein content of perennial ryegrass-white clover pastures means that nitrogen (N) in the feed usually exceeds the cows' requirements for milk production, resulting in large losses of N in urine (Tamminga, 1992). Urinary N (UN) is an environmental concern because it readily mineralises to nitrate which easily leaches into ground and surface water (Di and Cameron, 2002). Approaches to reduce UN of grazing cows include utilisation of ryegrass cultivars with lower crude protein (CP) and using plant species with higher rumen undegradable protein (see review by Totty et al., 2013). Recent studies have shown that use of diverse pastures (comprising grasses, legumes and herbs) can reduce UN excretion in late lactating cows, without negatively impacting milk yield (Nobilly et al., 2013; Totty et al., 2013; Woodward et al., 2013). This offers the prospect of increasing milk production at a farm system level without increasing the N footprint.

The objective of this study was, therefore, to use a whole-farm systems approach to model the environmental benefits (as determined by reduced UN excretion) of feeding diverse pastures to dairy cows.

Methods

Model simulations

The DairyNZ Whole Farm Model (WFM; Beukes et al., 2008) with the Molly cow model (Hanigan et al., 2009) was used to assess the performance of two dairy systems with 2-7 year old Holstein-Friesian x Jersey crossbred cows. The Scott Farm near Hamilton in the Waikato region (stocking rate = 3.2 cows/ha, planned start of calving = 01 July, final dry-off date = 04 May) and the Lincoln University Dairy Farm (LUDF) near Christchurch in the Canterbury region (stocking rate = 3.9, planned start of calving = 08 August, final dry-off date = 29 May) were modelled over the 2011-2012 season. The effect of diverse pastures was assessed using three scenarios; the standard pasture (the traditional New Zealand perennial ryegrass-white clover pasture mix; control), and this pasture combined with diverse pasture sown in 20 or 50% of the farm area (with the remainder sown in standard pasture). The diverse pasture comprised standard pasture in a mix with herbs (chicory (*Chicorium intybus*) and plantain (*Plantago lanceolata*)), prairie grass (*Bromus wildenowii*) and either lucerne (*Medicago sativa*) in the Waikato or red clover (*Trifolium pretense*) in Canterbury. Standard pasture growth in the DairyNZ WFM was climate-driven (Ruakura/Lincoln climate data, NIWA) using the Romera et al. (2009) pasture growth model. In Canterbury, pastures were irrigated when the soil moisture content dropped below 75%. Diverse pasture production was estimated using seasonal growth rates and annual herbage yields measured in diverse pastures for the two regions (Nobilly et al., 2013; Woodward et al., 2013). Feed quality for standard and diverse pastures were predicted by Molly from the feed composition generated using data from three studies (Burke, 2004; Nobilly et al., 2013; Woodward et al., 2013). The generated values for CP content and the ratio of water soluble carbohydrates (WSC):CP for the Waikato and Canterbury are shown in Figs. 1 and 2.

Daily diets consisted of a mixture of standard and diverse pastures, the allowance depending on the availability of each feed. Pasture silage (both regions) and maize silage (Waikato) were fed during feed deficits. Nitrogen fertiliser use was 142 kg N/ha/yr (Waikato) and 329 kg N/ha/yr (Canterbury). Dry cows remained on the farm in the Waikato in winter, but were grazed-off the farm in Canterbury. In Canterbury, lactating cows spent 4 hr/day on the stand-off pad when soils were wet to reduce pugging damage. The model outputs on which this study focused were herbage dry matter (DM) production, imported feed, milksolids production, N intake, and UN excreted and deposited onto paddocks.

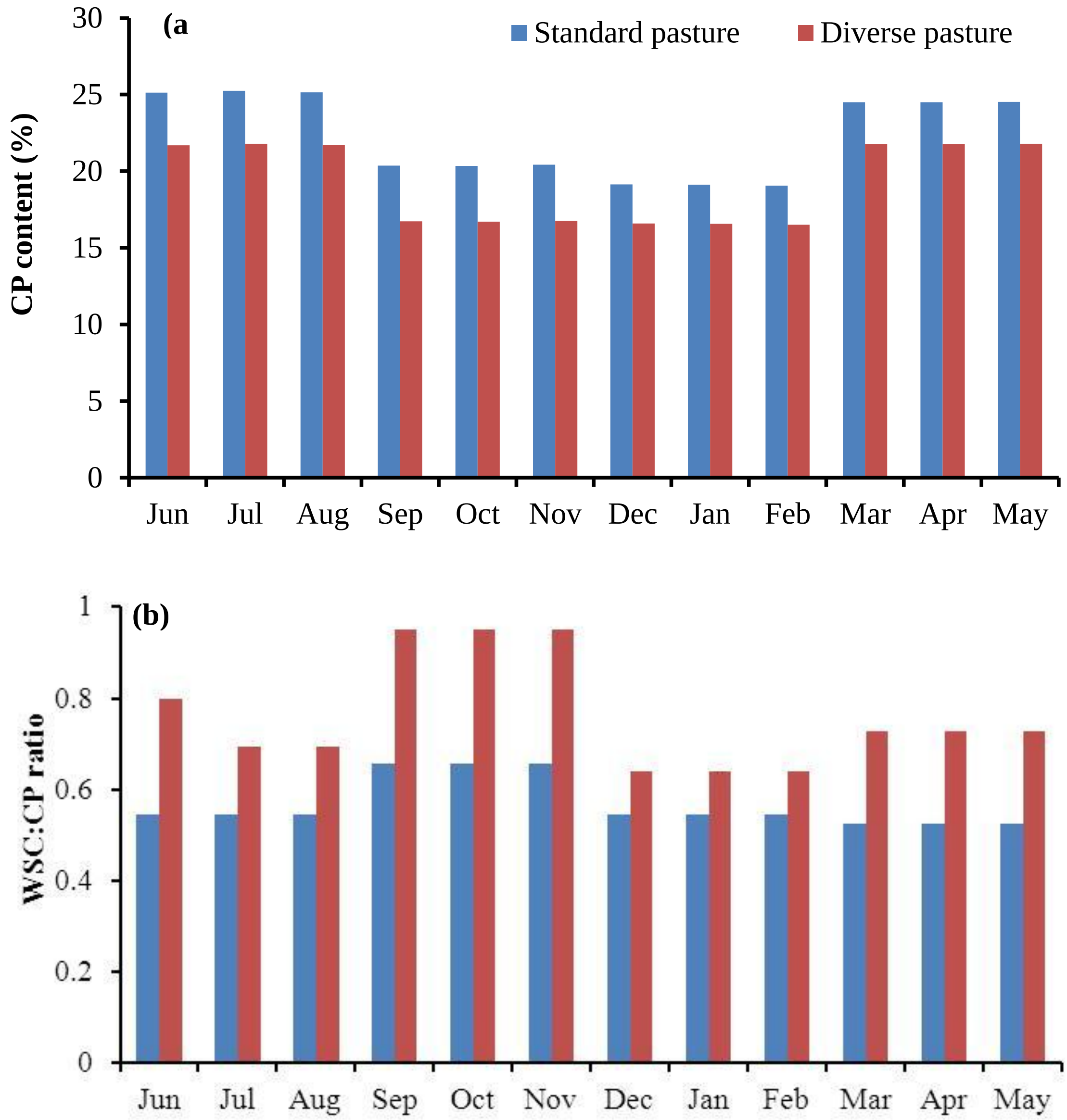

Figure 1: Crude protein (CP) content (a) and the ratio of water soluble carbohydrates (WSC):CP (b) for standard and diverse pastures in the Waikato - generated from Burke (2004) and Woodward et al. (2013) data.

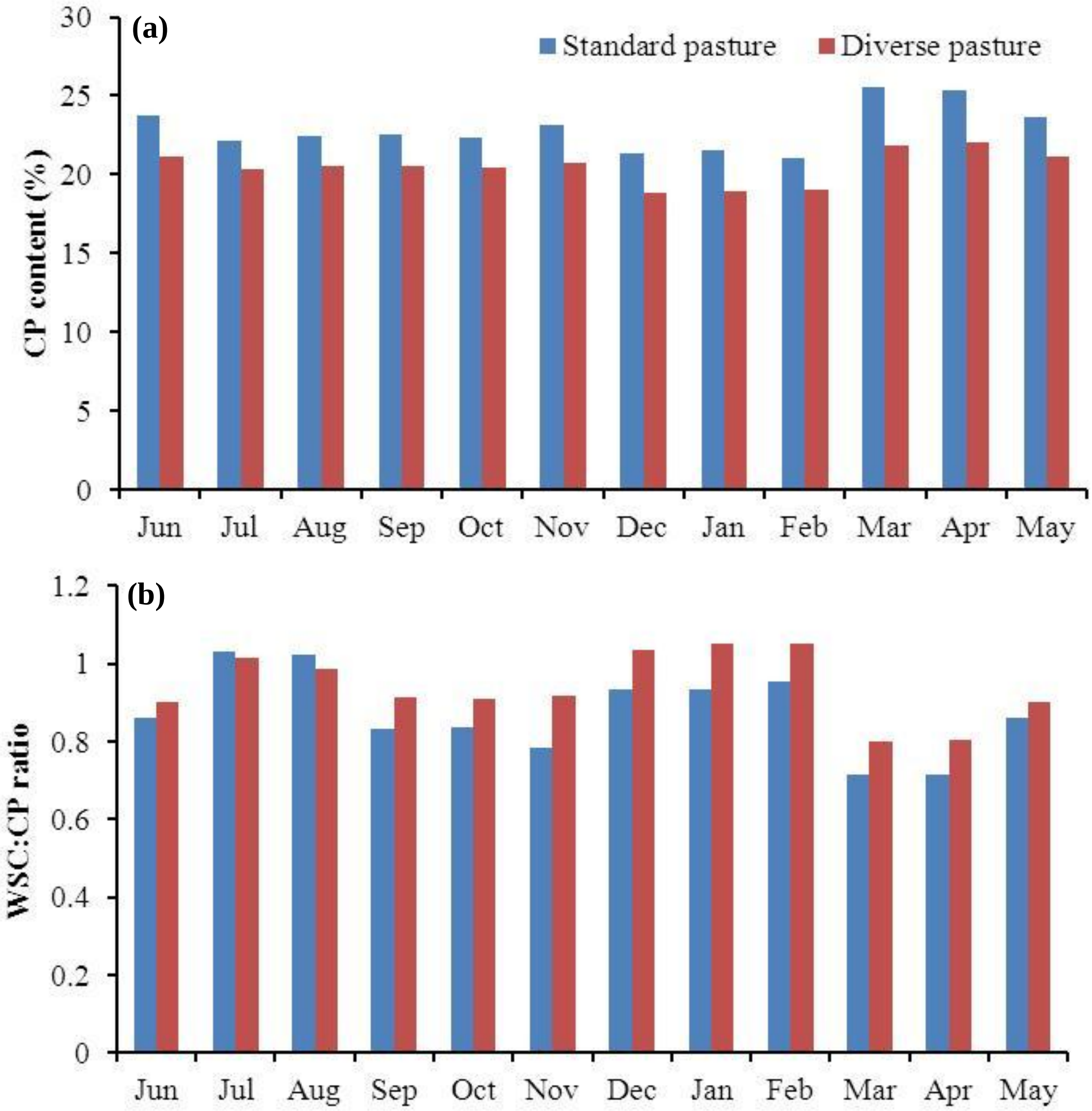

Figure 2: Crude protein (CP) content (a) and the ratio of water soluble carbohydrates (WSC):CP (b) for standard and diverse pastures in Canterbury - generated from Burke (2004) and Nobilly et al. (2013) data.

Results

Herbage dry matter yield, imported feed and milksolids production

In the Waikato, DM production was reduced by 2 and 6% when 20 and 50% of the farm was sown in diverse pasture, compared with sowing standard pasture in the whole farm (Table 1). Relative to the control, a 4% reduction and a 67% increase in purchased feed was predicted for the '20% diverse' and '50% diverse', respectively. Relative to the control, the '20% diverse' resulted in 1% reduction in per hectare milksolids production, while the '50% diverse' had a negligible effect. In Canterbury, the '20% diverse' resulted in 1% lower DM production, but about 2% increase in DM production was predicted for the '50% diverse', compared with the control. In this region, the farm purchased 19% less feed when 20% of the area was sown in diverse pasture, with a further 27% less imported feed predicted when the area sown in diverse pasture was increased to 50%. Compared with the control, milksolids production was reduced by 1% and increased by 3% when, respectively, 20 and 50% of the farm was sown in diverse pasture.

Table 1: Predicted herbage dry matter (DM) production, imported feed, milksolids production, N intake, urinary nitrogen (UN) excretion and UN deposited onto paddocks based on Waikato and Canterbury dairy farms feeding cows standard pasture sown in the whole farm (control) or standard pasture in combination with diverse pasture sown in 20 or 50% ('20 diverse' or '50% diverse') of the farm. UN = urinary N, Change (%) = Percentage change relative to the control, LUDF = Lincoln University Dairy Farm.

Modelled farm/region	Scenario	Herbage production (t DM /ha/yr)	Imported feed (kg DM /cow/yr)	Milksolids (kg/ha/yr)	N intake (g/cow/day)	UN (kg/ha/yr) – on milking platform	
						Excreted	Deposited onto paddocks
Scott/ Waikato	Control	17.6	270	1166	172	320	272
	'20% diverse'	17.2	260	1157	168	309	263
	Change (%)	-2.3	-3.7	-0.8	-1.9	-3.4	-3.3
	'50% diverse'	16.5	450	1167	163	294	250
	Change (%)	-6.3	+67	0	-5.3	-8.1	-8.1
LUDF/ Canterbury							
	Control	16.2	515	1651	186	419	269
	'20% diverse'	16.1	419	1634	183	405	258
	Change (%)	-0.6	-19	-1.0	-1.6	-3.3	-4.1
	'50% diverse'	16.5	279	1698	182	397	250
	Change (%)	+1.9	-46	+2.8	-2.5	-5.3	-7.1

Nitrogen intake and N excretion
Nitrogen intake and N excreted in urine decreased with increased proportions of diverse pasture in the diet (Table 1). Compared with the control, the '20% diverse' and '50% diverse', respectively, resulted in N intake reductions of 2 and 5% in Waikato and 2 and 3% in Canterbury. Urinary N excretion and UN deposited onto paddocks were 3 and 8% lower when cow grazed the '20% diverse' and '50% diverse' pastures compared with grazing standard pasture in Waikato. In Canterbury, the '20% diverse' and '50% diverse' pastures reduced UN excretion by 3 and 5% and UN discharge onto paddocks by 4 and 7%, compared with the control.

Discussion
Annual farm-grown DM production decreased with increasing proportion of the farm sown in diverse pastures in Waikato. The lower DM production of the '20% diverse' had a minimal impact on milksolids production, with the system requiring 4% less imported feed compared with the control. A possible explanation is that greater feed energy content (i.e. higher WSC:CP ratio; Tas, 2006) from inclusion of diverse pasture in 20% of the farm, more than compensated for reduced DM production. Thus, for the same amount of milksolids produced, cows required less of the '20% diverse' feed compared with the control. However, the '50% diverse' resulted in a 67% increase in imported feed, indicating the greater effect of reduced DM production compared with the benefit of increased feed energy, and a requirement of feeding the low energy maize and pasture silage. This suggests that in an average year (average year determined by the 17.6 t DM/ha/yr production for standard pasture), incorporating diverse pasture in >20% of the farm is likely to reduce total farm-grown feed with consequential negative impacts on economic performance of Waikato dairy systems.

In Canterbury, herbage DM and milksolids production were similar for the '20% diverse' and the control. However, 19% less feed was imported for the '20% diverse', probably reflecting increased energy content of the feed compared with the control. Contrary to the situation in the Waikato, the '50% diverse' resulted in greater DM which translated into increased milksolids production and less imported feed, compared with the control. A two-year study in this region also showed greater DM production from diverse than standard pasture (Nobilly et al. 2013). Given that increased summer DM production observed in both regions was the result of the dominance of summer tolerant chicory, plantain and/or lucerne (Nobilly et al. 2013; Woodward et al. 2013), greater productivity of diverse pasture in Canterbury compared with the Waikato was possibly due to an added response to irrigation. This suggests that incorporating diverse pasture in the irrigation-based Canterbury dairy systems has the potential to increase annual home-grown DM production with positive effects on milk production.

In both regions, diverse pastures resulted in less UN excretion, suggesting the potential for reduced N leaching risk when pasture diversity is incorporated in New Zealand dairy systems. The predictions in this study were of lower magnitude but consistent with data from outdoor (Totty et al. 2013) and indoor (Woodward et al. 2012) trials. In this study, the N intake from the '20% diverse' and the '50% diverse' pastures was lower compared with the control, and that may partly account for reduced UN. In addition, the WSC:CP ratio was greater for the diverse than standard pasture throughout the season in the Waikato and for most of the season in Canterbury. Increased WSC:CP ratio has been associated with improved synchrony of energy and protein supply to rumen microbes resulting in efficiency of N utilisation (Tas, 2006). This may have played a role in N partitioning resulting in reduced output of N in urine for diverse pasture scenarios.

Conclusions

This study shows that incorporating diverse pasture in New Zealand dairy systems has the potential to reduce UN excretion by dairy cows and N leaching. In the Waikato, consideration should be given to the proportion of the farm sown in diverse pasture since '50% diverse' reduced annual herbage DM production and increased the importation of supplementary feed. Canterbury dairy systems are likely to benefit more from incorporating diverse pastures because of the potentially higher response from irrigation. Persistence of diverse pasture and re-grassing costs were not taken into account in this modelling exercise and, therefore, these results will to verified by further studies.

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